V. GEOPHYSICS

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A. PERTURBATION OF A PLASMA BY A PROBE

Material previously reported in Technical Report 406, Research Laboratory of Electronics, M.I.T., December 26, 1962, has now been revised with additional experimental evidence supplied by R. Bullis of the United Aircraft Corporation Research Laboratory in private communications (also published in part in Advanced Energy Conversion 2, 523, 1962) and prepared for publication. A short summary follows.

The theory of the electrostatic probe immersed in a plasma is discussed under the assumptions that particle mean-free paths are comparable to or smaller than probe $\lambda_c/r_p < 10$, $r_p/100\,\lambda_D > 1$, $\lambda_c/\lambda_D > 10$, where r_p is probe radius, λ_c is particle mean-free path, and λ_D is the Debye length. In the limit as λ_c/r_p approaches infinity, the results converge toward the Langmuir result for the same probe. The probe-current vs voltage characteristic obtained when mean-free paths are short is distorted because the degree of perturbation of plasma density and potential vary with probe voltage. An unexpected result is that the shape of the probe characteristic in the vicinity of the "knee" is sensitive to ion temperature, and may possibly be used to determine the ion temperature.

J. F. Waymouth

B. PLASMA DIFFUSION IN A MAGNETIC FIELD

There has been considerable interest in low-pressure gas discharges in magnetic fields since the time when it was found that instabilities develop which increase the rate of charged-particle diffusion across the magnetic-field lines. (A good review of theory and experiment has been given by Hoh.[1]) The instabilities are only beginning to be understood theoretically; new experiments, for example, the recent work of D. L. Morse,[2] show that a great variety of instabilities can arise.

Three discharge tubes have been built to study the processes of plasma diffusion in a homogeneous magnetic field. The tubes are approximately 2.5 meters long with inside radii of 1.1, 2.76, and 4.76 cm, respectively. Seven probes, arranged as in Fig. V-1, are used to measure axial and radial potential drop; three probes can be operated as Langmuir probes.

The tubes are placed in one of the National Magnet Laboratory's water-cooled solenoids[3]; this provides an axial magnetic field that is homogeneous within 2.5 per cent over

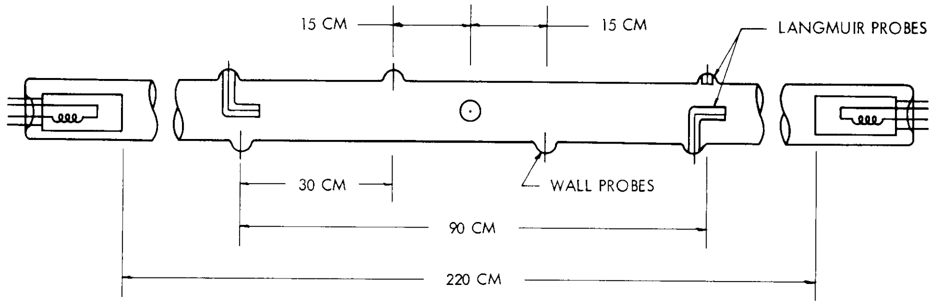

Fig. V-1. Probe arrangement.

a 140-cm length of the discharge. At the present time, the magnet is powered by a 70-kw power supply and is limited to fields below 3465 gauss. Experiments at higher fields can be conducted by using the large National Magnet Laboratory power supplies.

Preliminary measurements of axial electric field vs magnetic field for argon discharges in the 1.1-cm and 2.76-cm radii tubes are shown in Fig. V-2 for pressures of 0.1 and 1 mm Hg of argon.

The "normal" theory[1] of magnetoambipolar diffusion indicates that the axial electric

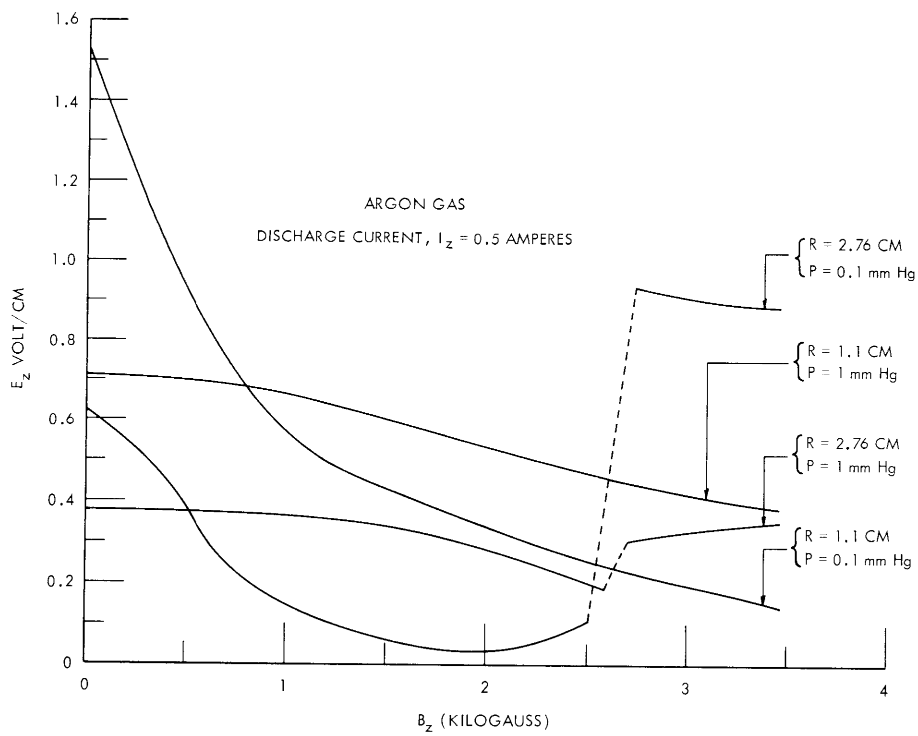

Fig. V-2. Axial electric field vs axial magnetic field. (Argon gas; discharge current, I_z = 0.5 amp.)

field should decrease monotonically with increasing magnetic field. This is apparently the case for the 1.1-cm radius tube up to B_z = 3465 gauss, but the 2.76-cm tube shows behavior similar to that originally studied by Lehnert.[1] It appears that the initial upturn of the E_z curve for R = 2.76 cm, p = 0.1 mm Hg is associated with a local instability at the end field coil nearest the anode of the discharge tube. The large discontinuity at 2600 gauss, on the other hand, involves the entire length of the plasma column within the magnetic field.

In the future, helium, mercury-helium, and mercury-argon discharges will be investigated as a function of discharge parameters and magnetic field, and the electromagnetic radiation emanating from the tube will be studied.

W. D. Halverson

References

1. F. C. Hoh, Low-temperature plasma diffusion in a magnetic field, Revs. Modern Phys. 34, 267 (1962).

2. D. L. Morse, Rotating plasma instabilities, Quarterly Progress Report No. 71, Research Laboratory of Electronics, M.I.T., October 15, 1963, pp. 116-122.

3. F. Bitter and W. D. Halverson, High-power solenoid electromagnet, Quarterly Progress Report No. 66, Research Laboratory of Electronics, M.I.T., July 15, 1962, pp. 12-14.

C. LEVEL CROSSING IN Hg^{199}

The level-crossing method[1] of atomic spectroscopy which was used in this experiment involves the observation of the decrease of intensity of the resonance fluorescence

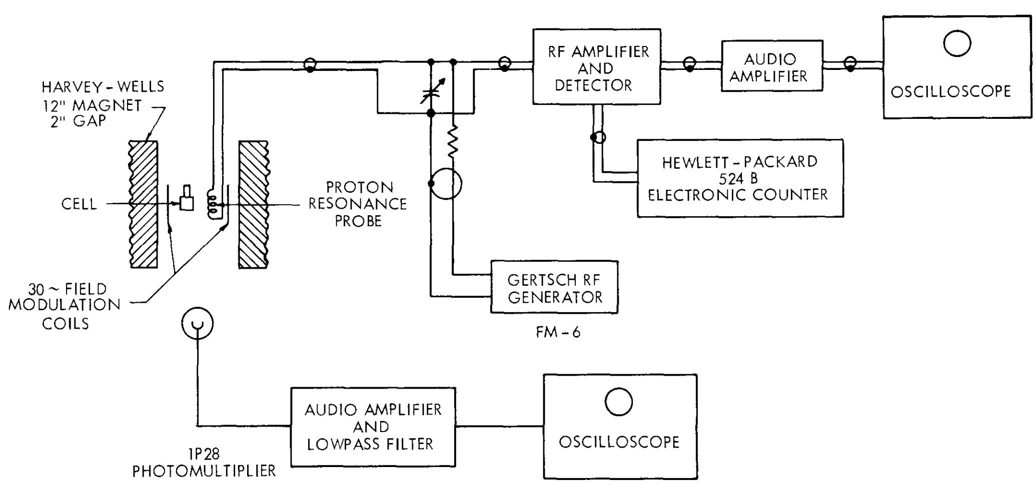

Fig. V-3. **Proton resonance and level-crossing detection systems.**

at a 90° scattering angle when two Zeeman levels of the 6s6p $^3P_1$ state of Hg^{199} are brought into coincidence ("crossed") through the application of a magnetic field. The previous precision measurements[2,3] of this type gave results for the magnetic field at which the Hg^{199} crossing occurs which do not agree within their limits of error, and hence a remeasurement was desirable.

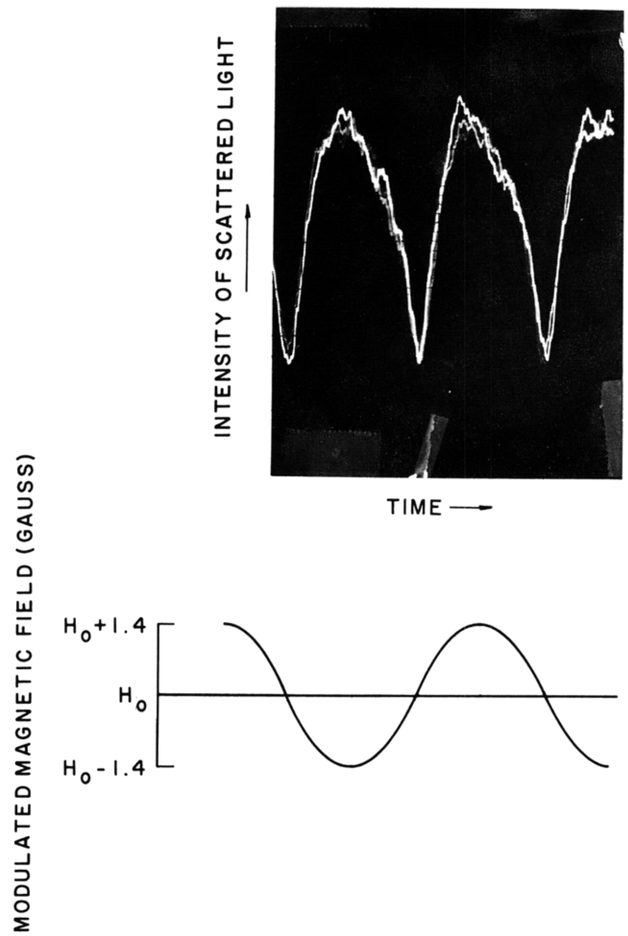

Fig. V-4. Level-crossing signal with magnetic field modulated at 30 cps. H_o is the level-crossing field. Scattering angle adjusted to 90°. Cell at room temperature.

The magnets and optical system used in this experiment were the same as those used by Smith.[3] New apparatus that should make possible more accurate measurements is described. Precision measurements of the magnetic field at the position of the 1-cm cubical cell containing natural mercury were made by using a proton resonance probe that could be moved to the location of the cell after the magnetic field has been adjusted to the level-crossing value. With the magnet power supply used (Harvey-Wells 1365B), the stability of current was such that the magnetic field changes during a measurement (~5 sec interval) were less than one part in 10^6. In order to eliminate errors caused by changes of frequency of the rf source that was used for proton resonance, a system (Fig. V-3) having frequency stability better than one part in 10^7 over the time of a measurement was used. The level-crossing and proton-resonance signals were observed simultaneously on two oscilloscopes. See Fig. V-4 and V-5.

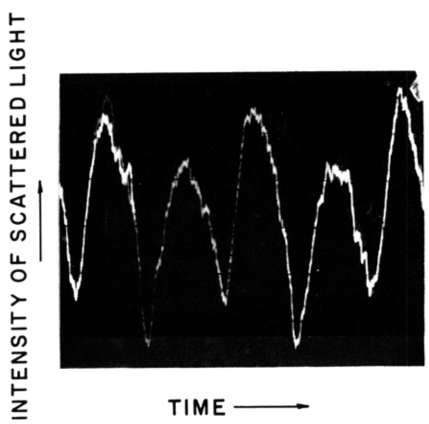

Fig. V-5. Level-crossing signal with scattering angle approximately 100°.

Due to a change of line shape from pure Lorentzian to a mixture of dispersion and Lorentzian line shapes upon a deviation of scattering angle from 90°, the minimum point of the line shape shifts away from the level-crossing point. The adjustment of the effective scattering angle to 90° was made by observing asymmetry of line shape with oscilloscope display. See Fig. V-5.

Results:

Proton resonance frequency at crossing field of Hg^{199}

30198.14 ± .15 kc (Protons in 0.01 molal H_2O solution of $FeCl_3$)

This value can be compared with the previous precision results:

Reference	Proton Resonance Frequency at Hg^{199} Level Crossing
2	30197.37 ± .15 kc
3	30197.95 ± .36

O. Redi

References

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D. OBSERVATIONS OF THE AEROSOL LAYER AT 20 km*

The existence of an aerosol layer at approximately 20 km altitude has been well established by optical techniques[1-3] and by direct sampling from balloons and aircraft

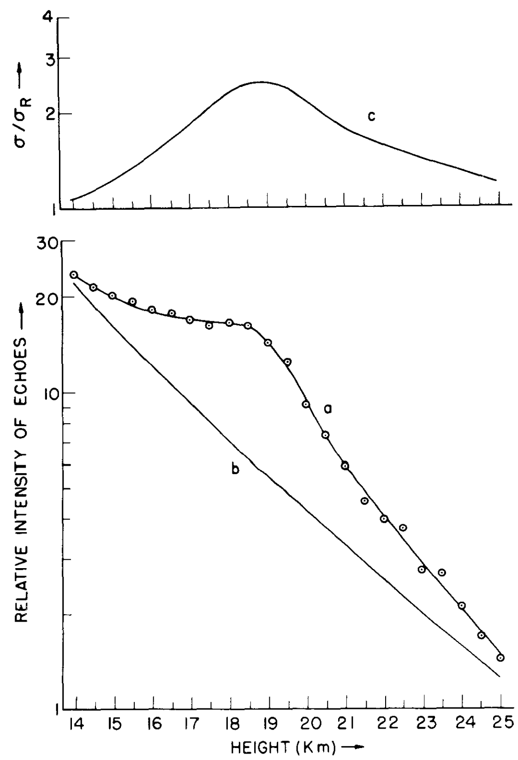

Fig. V-6. Intensity of echoes: curve a, experimental results; curve b, computed echoes from standard molecular atmosphere; curve c, ratio of curve a to curve b, interpreted as the ratio of the total backscattering cross section σ to the molecular backscattering cross section σ_R.

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(see, for example, Junge and Manson[4]). Preliminary results of observations of this layer with an optical radar are reported here.

The optical radar system, which has a pulsed ruby laser as the source of radiation, presents some changes and improvements over the instrumentation previously utilized.[5,6] The receiving telescope is of the Dahl-Kirkham type with 40-cm aperture. The detector incorporates a mechanical shutter to prevent exposing the photomultiplier to the strong echoes from short distances. The wavelength is 0.694 micron.

At the present time, the technique gives profiles of the backscattering radar cross section of the atmospheric constituents as a function of height; since the component attributable to molecular scattering can be separately evaluated on the basis of known model atmospheres, anomalous contributions caused by the presence of aerosols, in some cases, can be isolated. A profile of the relative intensity of the echoes from 14-15 km altitudes is represented by curve a in Fig. V-6. This profile was obtained by averaging 20 successive traces to eliminate fluctuations; the traces were taken during a sixteen-minute interval (2247-2303 E. S. T.), 14 February 1964, at Lexington, Massachusetts. Curve b in Fig. V-6 is a theoretical curve of the echo intensity for a model molecular atmosphere. Because an absolute calibration for the apparatus is not available at this time, the relative position of the two curves is subject to uncertainty; in particular, curve b was constructed to agree with the experimental curve a at the extreme ranges. The signal at ~20 km is much greater than is expected in the molecular atmosphere, indicating the presence of a large aerosol component. The ratio of the total backscattering cross section σ to the molecular backscattering cross section σ_R was evaluated from the previous curve, and it is shown as curve c in Fig. V-6. This curve is in fair agreement with published profiles of scattering cross sections for this layer.[3]

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